INFRARED RADIATION FOR THE CONTROL OF IMMATURE INSECTS IN KERNELS OF ROUGH RICE

UNITED STATES DEPARTMENT OF AGRICULTURE
Agricultural Marketing Service
Market Quality Research Division

AMS- 445

Acknowledgments

These experiments were carried out in cooperation with the Department of Plant Physiology and Pathology, Texas Agricultural Experiment Station.

The Data Processing Center, A & M College of Texas, assisted in the statistical analyses.

May 1961

INFRARED RADIATION FOR THE CONTROL OF IMMATURE INSECTS IN KERNELS OF ROUGH RICE

By

Harry W. Schroeder and Elvin W. Tilton[1]
Market Quality Research Division
Agricultural Marketing Service

Summary

Laboratory tests were conducted at College Station and Houston, Tex., to determine the effect of irradiation with infrared from a ceramic panel gas-sired infrared heater on immature rice weevils, Sitophilus oryzae (L.), and lesser grain borers, Rhyzopertha dominica (F.), feeding on rough rice.

Both species were completely controlled by treatments previously shown to be non-detrimental to the milling quality of rough rice.

The temperature to which the rice was heated during treatment appeared to be the most important factor in determining the mortality rate. Rice weevils and lesser grain borers were controlled with mean temperatures of 56° and 68° C., respectively.

Differences between the two species in their reaction to treatment with infrared appeared to be related to the stage of development of the immature forms.

Introduction

Experiments conducted by Schroeder[2] and by Schroeder and Rosberg[3, 4] have demonstrated the possibility of drying rice with infrared radiation from a gas-fired ceramic panel heater. These workers reported that rough rice dried rapidly when subjected to temperatures of 50° to 70° C. in irradiation periods of 10 and 20 seconds, and this treatment did not lower the yield of head rice significantly. Since these temperatures are in the range which may be lethal to insects, the possibility of controlling insects in rice by infrared drying was suggested.

Yeomans[5] concluded that the use of infrared radiation for the control of insects was not practical because of the expense, and because penetration by this wave length is poor. At that time the heat was produced by incandescent bulbs. Now, the cost of producing heat with the gas-fired ceramic panel infrared heater is quite low.

Small laboratory tests were conducted at College Station and Houston, Tex., to determine the effects of infrared radiation on stored-rice insects which feed within the rice kernel. The rice weevil, Sitophilus oryzae (L.) and the lesser grain borer, Rhyzopertha dominica (F.) were selected for these experiments.

---

[1] Dr. Schroeder is plant pathologist, Field Crops & Animal Products Branch, College Station, Tex.; Mr. Tilton is entomologist, Stored-Rice Insects Laboratory, Houston, Tex.

[2] Schroeder, H. W. Infrared drying of rough rice. II. Short grain types; Calrose and Caloro. Rice Jour., Vol. 63, No. 13, December, 1960.

[3] Schroeder, H. W. and Rosberg, D. W. Drying rough rice with infrared radiation. Tex. Agr. Expt. Sta. Misc. Pub. 354.

[4] Schroeder, H. W. and Rosberg, D. W. Infrared drying of rough rice. I. Long grain types; Rexoro and Bluebonnet 50. Rice Jour., Vol. 63, No. 12, Nov. 1960.

[5] Yeomans, A. H. Radiant Energy and Insects. Insects, Yearbook of Agriculture, U. S. Dept. of Agr., 1952, pp-411-421.

Procedure

Century Patna rough rice containing 12.2 percent moisture[1] was used in the first experiment. At the beginning of each week, for 4 weeks, approximately 2,500 grams of rice were infested with 1-month-old adult rice weevils and lesser grain borers. Adult insects were removed from each sample at the end of a week; at the end of 4 weeks the 4 samples were combined and thoroughly mixed. The combined sample was then subdivided into 40 parts, each part containing 250 grams of infested rice.

Century Patna rough rice containing 12.1 percent moisture[2] was used in the second experiment. Rice was infested by the method described above except that four lots were infested with rice weevils only, and four lots with lesser grain borers only; forty 200-gram samples containing each species were treated.

The infested samples were placed in pint Mason jars with filter paper covers until they were treated with infrared radiation.

The infested rice was placed in screened trays in layers about one kernel deep, and irradiated. Trays with a surface area of one square foot were used in the second experiment in order to calculate the energy used in each treatment in irradiating a unit weight of rice.

A ceramic panel gas-fired infrared heater with a rated input of 48,000 Btu per hour was used. The intensity of the radiation was varied by increasing or decreasing the distance between the rice and the heater. Radiation intensity and total energy input per treatment were calculated on the bases of the rated Btu-input, of the heater and the area irradiated at a given distance from the heater.

In the first experiment a laboratory thermometer was placed at the level of the rice until a predetermined temperature was reached. The tray was then removed from beneath the heater and the exposure time recorded.

The method described above gave only approximate temperatures of the rice. A different procedure was followed in the second experiment to yield more exact information. The rice was exposed for a predetermined time at three radiation intensities. The irradiation-time levels were calculated to give the same three levels of input energy per sample for each of the three intensity levels in order to study the effect of time of heating on the mortality rate of the insects. Immediately after irradiation each sample was weighed, returned to its container, and its temperature determined by inserting a thermistor surface-temperature probe into the rice. The filter paper covers were then replaced on the jars. Samples were selected for treatment in a random fashion and each treatment was replicated four times. Replications were treated at different times. Four samples of each species of insect, not irradiated, served as controls.

Samples from both experiments were incubated in a room at 86° F. and 60 percent relative humidity.

In the first experiment adult insects were removed and counted 5 weeks after treatment; in the second they were removed and counted at intervals throughout the period of emergence.

Results

Experiment 1.--The results indicate that irradiation of rough rice with infrared at intensities and exposures known to be harmless to the rice can be lethal to immature

---

[1] Determined by Tag-Heppenstall moisture meter.
[2] Determined by two-stage oven drying.

stages of rice weevils and lesser grain borers (table 1). There appeared to be a definite difference between the susceptibility of the two species to a given treatment.

Experiment 2.--The data obtained in the second experiment and their analyses are given in tables 2 through 9.

The mean temperatures of the irradiated samples ranged from 40° to 68° C., and the means of the moisture removed by irradiation ranged from 0.5 g. to 1.8 g. (table 2). The means for corresponding treatments of samples containing rice weevils and lesser grain borers appear to agree within the range of experimental error. The calculated radiation intensity in Btu-input per square foot per hour and the total energy input per sample treated are also shown in table 2, in relation to the distance between the rice and the heater during treatment and in the length of the exposure period. Total energy input is considered to be at three levels of the same magnitude for each of the three intensity levels for purposes of the analysis as given in table 5.

The distance between the rice and the heater was calculated to allow the use of a ratio of approximately 1:2:3 for intensities, length of irradiation, and total energy input per sample. Equal temperatures of the rice were expected when equal amounts of energy per sample were expended; however, the data in table 2 show clearly that the time factor, even for irradiation periods of less than a minute, influences the final temperature.

The analyses of variance of total emergence of rice weevils and lesser grain borers showed the effect of treatments to be highly significant (table 4). All treatments reduced emergence by significant numbers. With the rice weevil, emergence was reduced 33 to 100 percent and with the lesser grain borer, 54 to 100 percent.

The emergence data were analyzed in order to determine the significance of radiation intensity, energy input per sample, species differences, and date of emergence (table 5). Emergence data were converted to emergence in percent of the control in order that valid comparison between the two species could be made.

The total energy input per sample had a highly significant effect on emergence, which was significantly different at each of the three energy input levels (table 6). Emergence was inversely proportional to total energy input.

The average emergence of insects by the date of emergence is shown in table 7. The insects emerged in the greatest numbers in 14 to 23 days after treatment. There was another significant peak emergence period 30 to 37 days after treatment.

The interactions of date of emergence x species and the date of emergence x energy input per sample were also highly significant. It is apparent that the two species either reacted differently to treatment with infrared at certain stages of their life cycles or that the species were present in disproportionate numbers of the various life stages at the time of treatment. The mean emergence of rice weevils is compared by dates of emergence with the emergence of the lesser grain borer in table 8.

The other significant interaction, date of emergence x total energy input, indicates a differential emergence on certain dates between different energy-input levels. The mean emergence by date and by energy-input level is given in table 9.

Discussion

The data presented indicate that rice weevils and lesser grain borers in rough rice can be controlled by irradiation with infrared. Applications of the gas-fired infrared heater to the drying of rough rice would have the additional benefit of killing all stages of these stored-rice insects in the rice during the drying process. Rough rice could then go into storage free of insects. It could be expected to remain in that condition with a minimum

use of fumigants, provided that sources of infestation in and near the storage facilities were prevented from developing.

The data indicate that insect mortality is a function of the temperature to which the rice is heated. In this experiment rice weevils were completely controlled at rice temperatures averaging 56° C. and lesser grain borers at 68° C. The correlation coefficients between temperature and emergence are: (1) Rice weevils, -.8802 and (2) lesser grain borers, -.8388; $r = .403$ for $P = .01$ with 38 degrees of freedom.

The rate at which the temperature of the rice is increased (a function of radiation intensity) appears to be another factor in insect mortality. The data indicate that the more rapid the rise in temperature the more insects are killed. This phase of the study needs further investigation; however, it is apparent that high radiation intensities are most efficient in heating the rice to the desired temperature under the conditions of these experiments.

The data from both experiments show that the lesser grain borer may be more difficult to kill than the rice weevil. This difference seems to be related to certain stages of the insects as shown by the highly significant interaction between date of emergence x species and date of emergence x energy-input level. There are several factors which prevent the drawing of conclusions from the present data: (1) The rate of infestation was three times greater for the lesser grain borer, and (2) we do not know the relative prevalence of corresponding life stage.

TABLE 1.--Insects emerging from 250-gram samples of infested Century Patna rough rice 5 weeks after various exposures to infrared radiations

[Means of four replications]

Distance from heater and approximate temperature of sample	Rice weevil		Lesser grain borer	
	Exposure time	Total emergence	Exposure time	Total emergence
	Seconds	*Weevils*	*Seconds*	*Borers*
10 inches:				
40°C..................	13	1.75	14	3.75
45°C..................	17	0	18	.75
50°C..................	21	0	21	0
15 inches:				
40°C..................	18	0	21	3.00
45°C..................	25	0	26	.25
50°C..................	36	0	36	.25
20 inches:				
40°C..................	30	.25	30	.25
45°C..................	45	0	42	0
50°C..................	53	0	56	.50
Controls....................	0	10.75	0	18.50

TABLE 2.--Temperature and moisture loss of 200-gram samples of insect-infested Century Patna rough rice after various exposures to infrared radiation[1]

[Means of four replications]

Distance from heater, radiation intensity, exposure time, and energy input	Temperature of treated rice samples infested with--		Moisture removed by irradiation from rice samples infested with--	
	Weevils	Lesser grain borers	Weevils	Lesser grain borers
6 inches (4,748 $Btu/Ft^2/Hr$):	°C.	°C.	*Grams*	*Grams*
5 seconds (6.6 Btu)............	47	47	0.8	0.6
10 seconds (13.2 Btu)...........	54	57	1.1	1.1
15 seconds (19.8 Btu)...........	66	68	1.8	1.7
14 inches (2,310 $Btu/Ft^2/Hr$):				
10 seconds (6.4 Btu)............	44	41	.5	.5
20 seconds (12.8 Btu)...........	51	55	.9	1.0
30 seconds (19.2 Btu)...........	58	61	1.6	1.5
20 inches (1,543 $Btu/Ft^2/Hr$):				
15 seconds (6.4 Btu)............	42	40	.5	.5
30 seconds (12.9 Btu)...........	51	53	.9	.9
45 seconds (19.3 Btu)...........	56	59	1.4	1.4

[1] Temperature of all samples was 26° C. before treatment. Controls were kept at room temperature.

TABLE 3.--Emergence of rice weevils and lesser grain borers from 200-gram samples of infested Century Patna rough rice after various exposures to infrared radiation

[Means of four replications]

Radiation intensity and energy input per sample	Days after treatment--										Total emergence	
	14		23		30		37		44			
	RW	LGB	RW	LGB	RW	LGB	RW	LGB	RW	LGB	RW	LGB
4,748 Btu/Ft²/Hr:												
6.5 Btu........	3.25	0.75	1.00	1.00	0.25	0.25	0.25	1.00	0	2.25	4.75	5.50
13.0 Btu........	.25	0	.50	.00	.25	.50	.50	.00	0	.75	1.50	1.00
19.4 Btu........	.00	0	.00	.00	.00	.00	.00	.00	0	.00	.00	.00
2,310 Btu/Ft²/Hr:												
6.5 Btu........	3.25	4.00	1.75	2.25	.25	3.25	.00	5.00	.00	1.00	5.25	15.50
13.0 Btu........	.75	.75	.50	.50	.25	.50	.00	.75	.00	.25	1.50	2.75
19.4 Btu........	0	0	.00	.75	.00	.00	.00	.00	.00	.25	.00	1.00
1,543 Btu/Ft²/Hr:												
6.5 Btu........	4.75	6.00	2.00	4.00	.00	1.75	.25	1.75	.00	2.00	7.00	15.50
13.0 Btu........	1.75	2.50	.50	.75	.50	.75	.25	.25	.00	1.50	3.00	5.75
19.4 Btu........	.00	.00	.00	.50	.00	.00	.00	.00	.00	.25	.00	.75
Controls	7.25	17.50	.75	7.00	1.50	3.50	.75	.75	.25	4.75	10.50	33.50

TABLE 4.--Analyses of variance of total emergence of insects from rough rice treated with infrared radiation

Source of variation	Degrees of freedom	Sum of squares	Mean square	F value
Rice weevil				
Total................................	39	527.10		
Replications.........................	3	21.30	7.10	3.03*
Treatments...........................	9	442.60	49.18	21.10**
Error................................	27	63.20	2.34	
Standard error of mean difference = 1.082..				
Lesser grain borer				
Total................................	39	4,360.38		
Replications.........................	3	38.08	12.69	1.33
Treatments...........................	9	4,064.13	451.57	47.23**
Error................................	27	258.18	9.56	
Standard error of mean difference = 2.1866.				

*Exceeds the 5% level of significance.
**Exceeds the 1% level of significance.

TABLE 5.--Analysis of variance of the effect of infrared radiation on the emergence of rice weevils and lesser grain borers from infested rough rice; based on emergence in percent of the control

Source of variation	Degrees of freedom	Sum of squares	Mean square	F value
Replications............	3	6,225.90	2,075.30	.54
Species.................	1	1,551.55	1,551.55	.41
Radiation intensity......	2	14,176.23	7,088.12	1.86
Energy input............	2	195,909.05	97,954.53	25.64**
Date of emergence........	4	100,664.89	25,166.22	6.59**
Species x Radiation......	2	1,818.20	909.10	.24
Species x Emergence......	2	2,185.64	1,092.82	.29
Species x Date...........	4	146,337.94	36,584.48	9.58**
Radiation x Emergence....	4	13,895.98	3,474.00	.91
Radiation x Date.........	8	18,141.54	2,267.69	.59
Emergence x Date.........	8	93,733.68	11,716.71	3.07**
Error................	319	1,218,655.93	3,820.24	
Total...................	359	1,813,296.39		

**Exceeds the 1% level of significance.

TABLE 6.--The mean emergence of rice weevils and lesser grain borers in relation to calculated energy input, given as percent of emergence of non-irradiated controls

Calculated total energy input	Emergence in percent of controls	Standard error of mean difference
6.5 B.t.u...............	57.6	
13.0 B.t.u...............	22.8	± 7.95
19.4 B.t.u...............	0.9	

TABLE 7.--The mean emergence of rice weevils and lesser grain borers in relation to date of emergence, given as percent of emergence of non-irradiated controls.

Date of Emergence	Emergence in percent of controls	Standard error of mean difference
February 8, 1960.............	15.2	
February 17, 1960............	54.0	
February 24, 1960............	17.8	± 10.30
March 2, 1960................	38.9	
March 9, 1960................	9.6	

TABLE 8.--The mean emergence of rice weevils compared to the mean emergence of lesser grain borers by date of emergence, given as percent of non-irradiated controls

Date of emergence	Emergence in percent of controls	
	Rice weevils	*Lesser grain borers*
February 8, 1960..................	21.5	8.9
February 17, 1960.................	92.6	15.5
February 24, 1960.................	13.3	22.2
March 2, 1960.....................	18.5	59.3
March 9, 1960.....................	0.0	19.3
Standard error of cross difference	± 20.60	

TABLE 9.--The mean emergence of rice weevils and lesser grain borers as affected by the interaction of total energy input and date of emergence, given as percent of non-irradiated controls.

Date of emergence	Emergence in percent of controls		
	Calculated total energy input		
	6.5 Btu	13.0 Btu	19.4 Btu
February 8, 1960..................	36.1	9.4	0.0
February 17, 1960.................	122.8	36.3	3.0
February 24, 1960.................	32.9	20.5	0.0
March 2, 1960.....................	77.8	38.9	0.0
March 9, 1960.....................	18.4	8.8	1.8
Standard error of cross difference.	± 25.27		